THE LOW LEVEL WIND SPEED MAXIMUM IN EAST TEXAS DURING AUGUST, 1977

by

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I. INTRODUCTION

The low level jet (LLJ) is a region of high wind speeds (generally greater than 24 knots) which occurs in the lowest kilometer or two of the earth's atmosphere. The jet plays a very important role in water vapor transport over east Texas and into the other Great Plains states. Warm, humid air is transported from the Gulf of Mexico inland via the low level jet. This flow of humid air plays an important role in several different processes. It has been associated with the occurrence of Gulf flow stratus over east and central Texas and into Oklahoma. This flow of humid air is also an important source of moisture for the middle-latitude storms of North America. These are just two of the many processes which have close ties with the low level jet. This study attempts to examine the relationships between the low level jet and some of these processes. Additionally, it will expand upon some recent works concerning the low level jet.

This study will begin by discussing a variety of theories concerning the reasons for the formation of the low level jet. The theories will be presented in a very general manner just to give the reader a background for understanding some of the phenomena associated with the jet. A variant of the concept of the low level jet which we will call the low level wind speed maximum will be defined. The only significant difference in the two will be the higher wind speeds associated with the low level jet. The rest of the study will then concern itself with the low level wind speed maximum.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to Dr. Norman K. Wagner and Dr. E. L. Koschmieder for their invaluable assistance and patience in supervising the preparation of this manuscript.

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The next section will discuss the data to be used for the rest of this study. The sources for the data will be given and the rationale for the choice of this particular data set will also be discussed. This discussion will be followed by a listing of the low level wind speed maxima determined from the data.

The fact that a nocturnal surface wind speed maximum occurs along the Texas coastline has been well established. (Yu and Wagner, 1970; Choi, 1984) This study attempts to determine whether a relationship exists between the elevated low level wind speed maximum and the coastal surface winds (including the nocturnal wind speed maximum). Another section of the study examines the relationship between wind shears at a variety of stations and the low level wind speed maximum. Both the speed and altitude of occurrence of the low level wind speed maximum are correlated to the average and maximum wind shears at five radiosonde stations.

To illustrate the importance of the low level wind speed maximum in the transport of water vapor, one section presents a simple vapor mass flux computation. The computation shows the inaccuracy of computing mass fluxes based only on information from the standard atmospheric levels.

The final section will discuss possible applications of low level wind shear information to a variety of fields. It will also summarize conclusions from the other sections.

II. FORMATION OF THE LOW LEVEL JET

A variety of theories exist which attempt to explain exactly what causes the low level jet to form. Several of these theories are outlined below. This is by no means an exhaustive listing, however, it is sufficient enough to show the evolution of thinking about the causes of the low level jet and to give the reader an introduction to a wide range of the most current theories.

Blackadar (1957) emphasized boundary layer mixing processes. As the boundary later stabilizes at sunset, there is a reduction in surface stress. This will, in turn, cause the wind speed to accelerate as a new equilibrium is established with the existing pressure gradient. During this period, the wind will even become supergeostrophic.

Wexler (1961) proposed a theory based on the topographic channeling of the Bermuda High. This theory predicted the formation of a jet stream when the Bermuda High extended westward enough to experience topographic channeling by the Rocky Mountains.

Uccellini and Johnson (1979) proposed a more synoptic scale theory. This theory concerned mass adjustment under jet streaks when the low level jet formed. Djuric and Damiani (1980), meanwhile, proposed a theory based on adiabatic warming on the leeside of the Rocky Mountains. Because of this warming, pressure begins to drop on the leeside. This pressure fall causes a southerly wind (LLJ) to develop over northwest Texas and eastern Colorado.

Still others (McNider, 1982; Friehe, 1982;

Broast, 1982) have used the differential heating of sloping terrain and the land/sea thermal contrast to explain the low level jet's formation. In these theories, the existing synoptic scale pressure gradient is reinforced by the mesoscale pressure gradients associated with the land/sea contrast and the differential heating of the sloping terrain. Inertial turning will then cause the winds to blow parallel to these gradients.

All of these latter theories (since 1979) have data which support them. This suggests that the low level jet might arise from any one, or a combination of several, meteorological processes. It would now be appropriate to give a specific definition of the low level jet for use in this study.

Djuric (1980) pointed out the difficulty in defining the low level jet. He noted that Bonner (1968) required that the wind speed must reach at least 12 m/sec and must decrease to half of its maximum value above the maximum. All this must occur below the 3 kilometer level. Choi (1984) similarly defined the low level jet. He said the maximum wind speed must equal 24 knots or greater. The speed must decrease by at least 4 knots within 1 kilometer above the maximum and the maximum must occur within an altitude of 2 kilometers above the ground. The most troubling part of these definitions is the arbitrary requirement for a threshold wind speed for the low level jet. In this study, as few arbitrary criteria will be used as is possible.

For the purposes of this study, the jet will be

defined as having a change in wind speed of at least 2 m/sec (4 knots) within 1 kilometer above and below the maximum wind. The maximum wind must also occur at or below an altitude of 1.5 kilometers. It is hoped that this definition will eliminate the arbitrary threshold wind speed requirement while retaining the classical low level jet wind profile (Fig. 1). Due to the fact that the maximum wind could have a very low speed and still satisfy this study's definition, it was believed that the use of the term low level jet would be inappropriate. Instead, the term low level wind speed maximum will be used for the rest of this study.

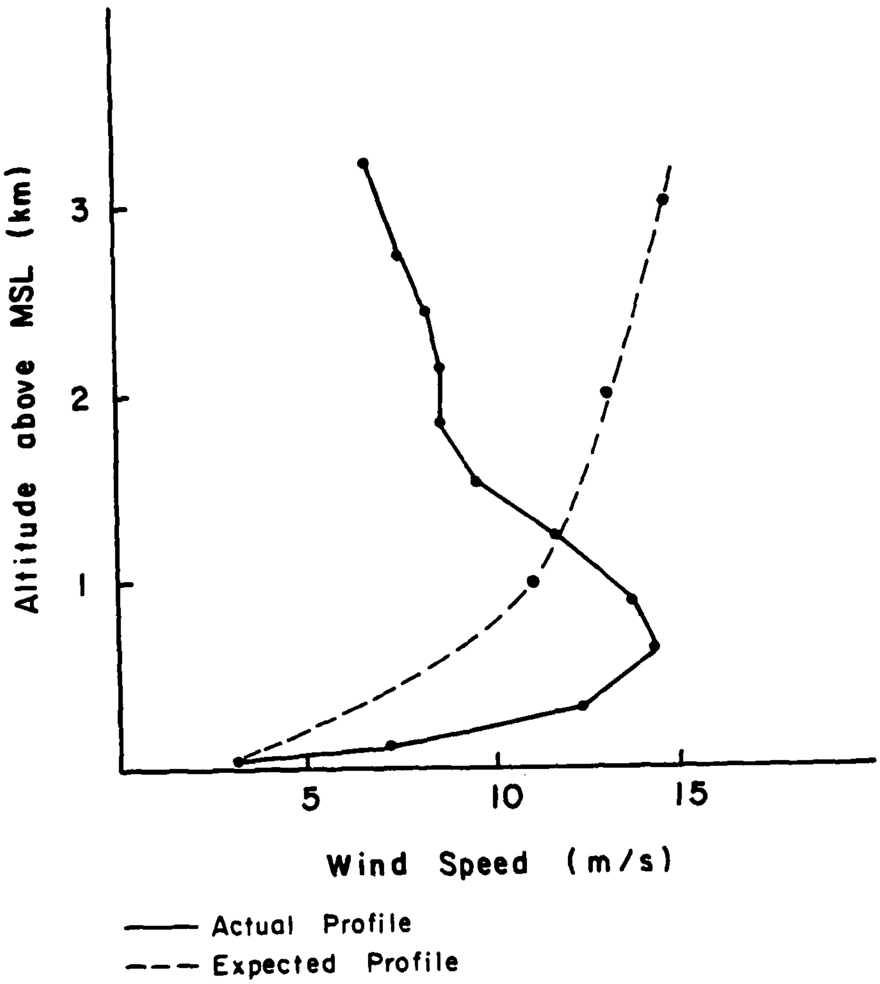

Figure 1. Typical low level jet wind profile (Brownsville, 1200 GMT, 1 Aug 77) with thermal wind profile for comparison

III. DATA

The data utilized in this report came from two primary sources. These sources were National Weather Service (NWS) teletype data and data obtained from a study done at Port Aransas, Texas.

Port Aransas Data

A unique source of information was available for this study. The source of this information was a 30 meter high tower located at Port Aransas, Texas (28^{o}N, 97^{o}W) (Fig. 2). This tower was installed by the University of Texas in June 1976. It is located approximately 0.5 kilometer inland from the Texas coastline at the Marine Science Laboratory in Port Aransas. The tower supplied a virtually continuous source of wind data from June 20, 1976 until it was destroyed by Hurricane Allan on August 10, 1980. The wind data was measured by a Bendix Aerovane model 610/MMQIA anemometer placed on top of the tower. This anemometer records the wind speed in the x and y components in statute miles per hour. Two Esterline-Angus strip chart recorders were used for each wind component. In reducing the wind information, an acetate overlay with time marks on it was used to convert the analog data on the strip charts into digital data. "Hourly" values were obtained by using a five minute time average centered on the hour. After conversion, the data was stored on magnetic tape.

This represents a unique collection of information because it gives a four year record of wind velocities at a coastal location. As noted in the

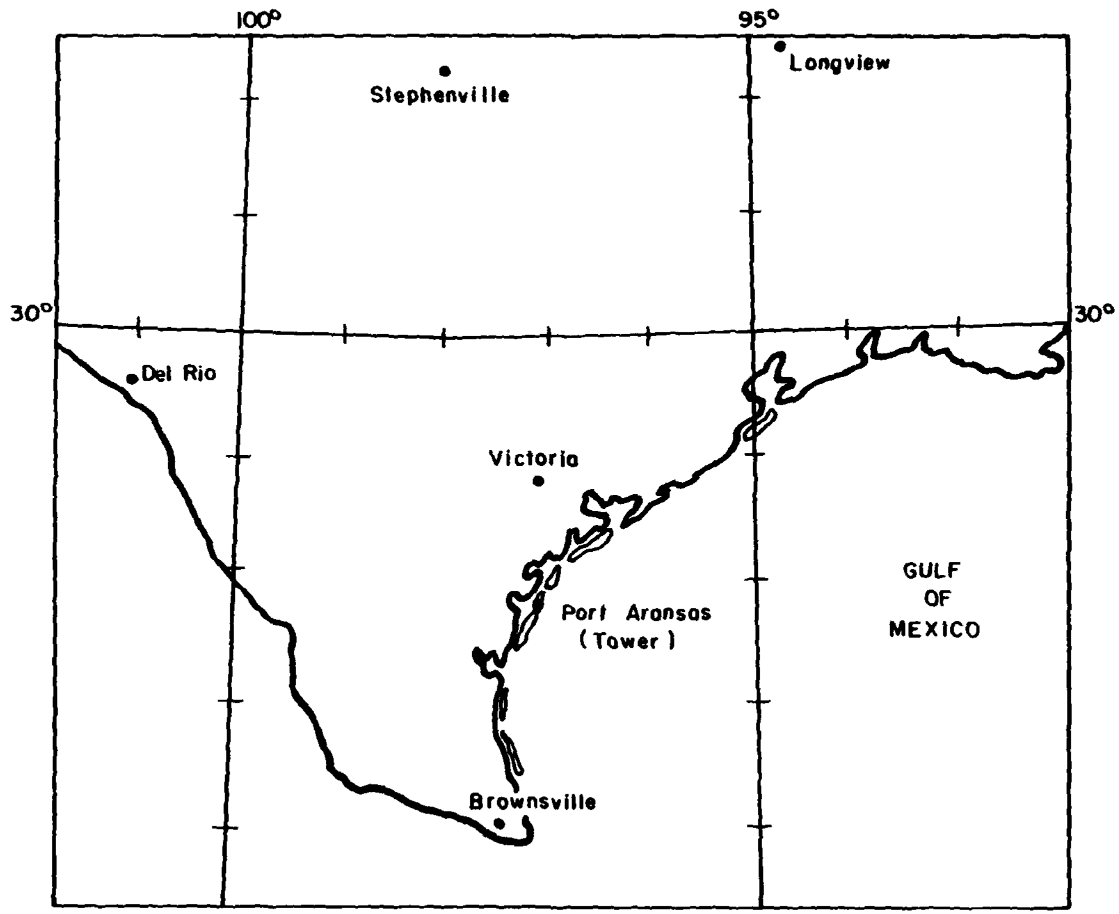

Figure 2. Map of southeastern Texas

literature, there are no first-order NWS weather stations which are truly "coastal" in nature (Choi, 1984). Therefore, having this information available provides an excellent opportunity to utilize coastal wind speed information in a study of the low level wind speed maximum.

In order to limit the scope of this study, after examining the entire four years of data, it was decided to focus this research on the month of August 1977. This month was fairly arbitrarily chosen although studies into the climatology of the low level jet show that it occurs most frequently in the summer months (Choi, 1984). A list of hourly wind speeds for Port Aransas for August 1977 is given in Table 1. These were converted to m/sec for use in this study.

NWS Data

The NWS teletype data consists of upper air data from five radiosonde stations located in southern and eastern Texas. These stations were Victoria (VCT), Del Rio (DRT), Brownsville (BRO), Stephenville (SEP), and Longview (GGG).

Victoria (29^{o}N, 97^{o}W) has an elevation of 36 meters above mean sea level (MSL). It is located 70 miles north of Port Aransas and approximately 45 miles inland from the coast. Del Rio (29^{o}N, 101^{o}W) has an elevation of 313 meters above MSL. It is 250 miles west-northwest of Port Aransas and 250 miles inland from the coast. Brownsville (26^{o}N, 97^{o}W) is 6 meters above MSL. It is 135 miles southwest of Port Aransas and 25 miles inland. Stephenville (32^{o}N, 98^{o}W) has an elevation of 402 meters above MSL. It is 313 miles

PORT ARANSAS, TEXAS
MARINE SCIENCE LABORATORY
THE UNIVERSITY OF TEXAS AT AUSTIN

AEROVANE TRANSMITTER
30 METERS HEIGHT
ESTERLINE-ANGUS RECORDERS

AUGUST 1977

HOURLY, HOURLY AVERAGE, DAILY AVERAGE, AND MONTHLY AVERAGE WIND SPEED IN MILES PER HOUR

CENTRAL STANDARD TIME

DATE	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	AVE
1	20	19	17	17	16	15	13	12	12	11	6	8	9	10	14	18	16	16	16	16	17	16	17	20	14.5
2	18	18	16	15	11	11	8	10	12	11	10	9	9	11	11	17	17	17	17	16	18	18	17	18	14.0
3	15	13	13	10	12	6	7	8	8	8	9	8	9	9	9	12	13	14	14	15	15	10	9	9	10.0
4	9	10	12	7	7	5	3	3	5	1	6	7	9	9	11	17	17	18	19	19	19	18	19	18	11.3
5	18	18	16	15	12	13	12	10	6	6	11	10	14	18	21	17	20	21	17	17	17	18	20	20	15.3
6	18	18	19	17	10	13	9	9	8	9	11	6	8	10	12	-99	-99	-99	-99	-99	-99	-99	-99	-99	11.8
7	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	12	14	18	17	18	17	16	16	16	15	16	15.7
8	16	16	14	13	13	12	12	9	6	6	8	9	9	11	13	13	16	15	16	16	15	15	15	15	12.6
9	19	15	14	12	10	10	9	10	9	10	9	10	10	14	15	14	18	17	17	16	18	21	22	18	13.7
10	17	16	15	12	11	10	8	6	2	7	8	9	9	9	11	12	18	13	15	16	16	15	13	13	11.5
11	12	12	11	9	7	7	4	2	3	5	7	8	9	12	12	13	18	14	13	13	13	12	10	9	9.6
12	11	9	8	7	6	4	2	8	9	7	6	10	6	8	11	13	10	14	10	13	13	12	11	10	9.5
13	9	8	10	11	10	11	7	4	8	6	6	7	9	12	18	15	17	17	18	17	15	19	20	21	11.8
14	23	22	20	20	19	19	16	15	15	13	12	14	15	14	17	18	19	19	18	19	21	18	17	17	17.6
15	17	14	18	19	16	16	15	13	14	14	10	16	17	19	19	18	19	18	18	17	-99	-99	-99	-99	16.7
16	20	20	20	20	17	16	13	12	11	10	9	11	11	12	16	14	16	16	17	17	17	17	15	18	15.0
17	14	11	10	9	9	7	5	5	6	5	9	6	8	9	10	13	15	16	12	13	14	16	10	13	10.4
18	11	13	10	10	9	7	6	7	5	2	6	9	5	8	8	9	8	11	9	10	8	10	13	15	8.7
19	13	16	14	15	10	12	15	11	11	14	13	12	12	14	17	17	21	22	23	22	22	25	20	25	16.6
20	24	19	18	19	19	21	18	18	17	17	15	16	15	15	19	21	21	22	21	21	23	22	20	24	19.6
21	23	23	23	19	21	20	18	19	16	15	16	12	14	16	18	19	20	20	21	21	21	20	18	18	18.8
22	20	20	16	16	16	13	13	18	15	19	19	17	16	17	18	20	21	23	24	20	23	23	20	20	19.1
23	25	27	25	23	21	21	20	20	21	18	19	20	20	23	20	22	20	25	24	24	22	22	21	20	22.3
24	21	19	18	19	19	17	16	16	13	12	16	16	18	16	16	16	18	18	19	20	18	17	18	19	17.2
25	18	17	17	15	15	16	16	13	13	18	18	15	14	16	18	19	20	21	21	22	21	21	20	18	17.3
26	18	18	14	17	15	15	13	12	13	12	11	11	11	12	15	15	16	17	19	19	19	19	18	19	15.8
27	20	19	20	17	9	15	21	19	16	19	18	16	16	19	19	21	19	17	21	18	20	19	21	23	18.5
28	22	24	22	16	24	15	21	24	17	14	11	8	7	8	9	13	12	11	11	15	15	17	17	18	15.5
29	16	18	15	15	13	12	11	11	13	6	3	6	6	7	9	13	15	17	18	16	16	15	15	15	12.6
30	10	7	5	1	10	13	9	10	10	11	11	9	11	11	15	16	18	22	19	19	18	20	20	18	13.1
31	17	13	10	11	12	15	8	17	13	15	16	17	17	17	18	21	20	20	20	25	25	20	20	20	18.1
AVE	17.0	16.5	15.5	14.5	13.6	12.9	11.6	11.5	10.6	10.7	11.0	11.1	11.5	12.9	14.7	16.9	17.1	17.0	17.0	17.8	17.7	17.0	17.8	17.7	10.7

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Table 1. Port Aransas hourly tower wind speeds

north-northwest of Port Aransas and 276 miles inland. Longview (32^{o}N, 95^{o}W) is 124 meters above MSL. It is 350 miles northeast of Port Aransas and 200 miles inland (Fig. 2).

The NWS takes radiosonde observations at each radiosonde station twice a day (0000 and 1200 GMT). These observations include temperature, moisture, and wind soundings. The 0000 and 1200 GMT observations for each of the five radiosonde stations were decoded and plotted on a Stüve diagram. This allowed the determination of the height and speed of the low level wind speed maximum as well as the determination of moisture variables at various levels.

As mentioned previously, August, 1977 was chosen as the basis for this study. An examination of all available 0000 and 1200 GMT observations for each of the five radiosonde stations was conducted. This examination revealed 157 occurrences of the low level wind speed maximum as shown in Table 2. Of these 157 occurrences, 108 occurred at 1200 GMT and only 49 at 0000 GMT. This represents more than a 2 to 1 ratio of occurrences at 1200 compared to 0000 GMT. This would certainly seem to support earlier postulates concerning reasons for the occurrence of the low level wind speed maximum. A frequency plot of these 157 occurrences of the low level wind speed maximum is shown in Figure 3. This frequency plot appeared to follow the normal probability distribution. When plotted on normal probability paper, the distribution did appear to follow the normal distribution quite closely (Fig. 4). Similar frequency plots were prepared for the 108 occurrences at 1200 GMT and 49 occurrences at 0000 GMT (Fig. 5).

Table 2. Low level wind speed maximum occurrences and speeds (m/sec) for 0000 GMT and 1200 GMT during August 1977.

	VCT		DRT		BRO		SEP		GGG	
Date	0000	1200	0000	1200	0000	1200	0000	1200	0000	1200
1	--	10.8		11.3		14.4		15.5	--	--
2	8.2	7.2		10.8		9.3		6.7	--	5.7
3		5.2	5.2	11.3	5.2	10.3		9.3	--	--
4		6.7		13.4		9.8		14.9		7.7
5	9.8	--		12.4	9.3	11.9		11.3	--	8.8
6	10.3	--	10.8	--	10.8	--		--	--	--
7	7.2	9.3		11.3			13.4	12.9	8.2	9.8
8		--		11.3				13.4	--	13.9
9	9.8	--	11.3	12.4	8.8				13.9	7.7
10			10.8	12.4	10.3	9.8	9.3	10.8	--	7.7
11	7.2		8.8	10.3		6.7	7.2	10.3		--
12				7.2	8.8	8.8				--
13		4.6		9.3	--		6.7	9.3		--
14	--	--	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--
16	--	8.8	--	11.3	--	10.8	--	11.3	--	10.8
17		6.2	10.8	10.3	8.8	7.7		7.2	--	10.8
18	8.2			8.8		7.2		9.3	--	
19		7.7		9.3	--	--		8.8	--	6.7
20		10.8	8.8	10.8	10.3	11.9		9.8	5.7	7.2
21		11.9	8.2	11.3	11.9	14.4		6.7	--	9.8
22	11.9	9.8	7.7	9.8	--	10.3		14.4	--	
23		13.4		11.9		17.0		5.7		12.9
24		11.9		10.3	14.4	14.4		8.8		6.7
25	9.3	9.3		10.3	10.8	13.9		15.5	6.2	--
26		11.3	11.3	15.5	12.4	11.9		19.1		10.3
27	10.8	14.4	13.4	16.0	--		13.4	14.4	8.2	
28		14.9	12.4	9.8	10.8	18.0			16.0	12.9
29				12.4		--		8.8	--	7.2
30	10.3	5.7			7.2			9.3		11.9
31		7.7		9.3	10.3					

-- indicates data was missing

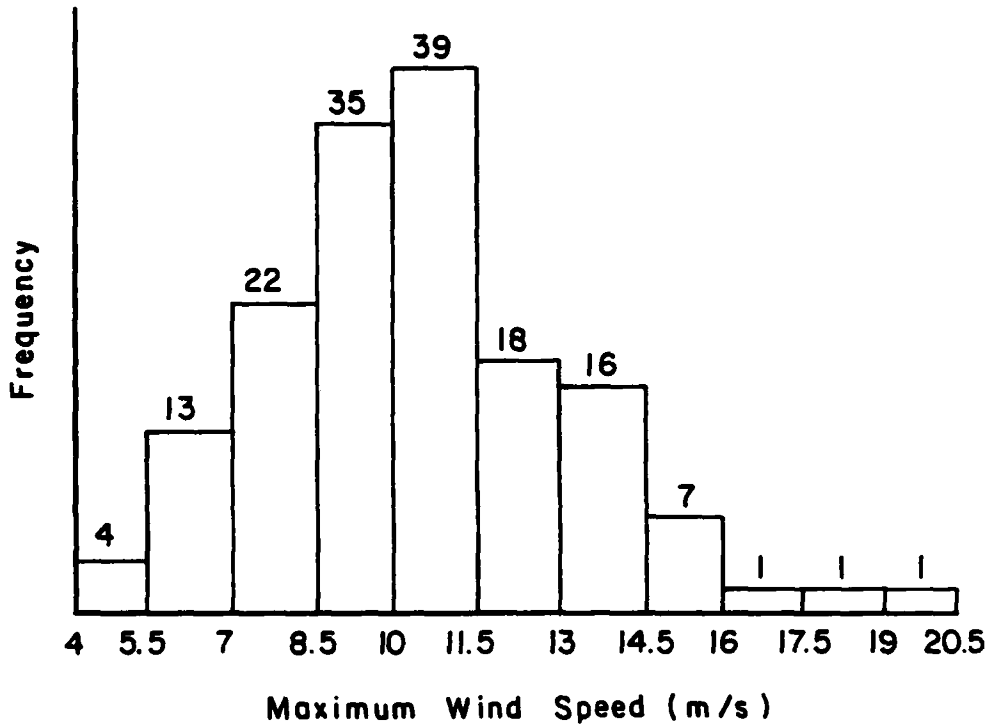

Figure 3. Frequency of low level wind speed maximum occurrences

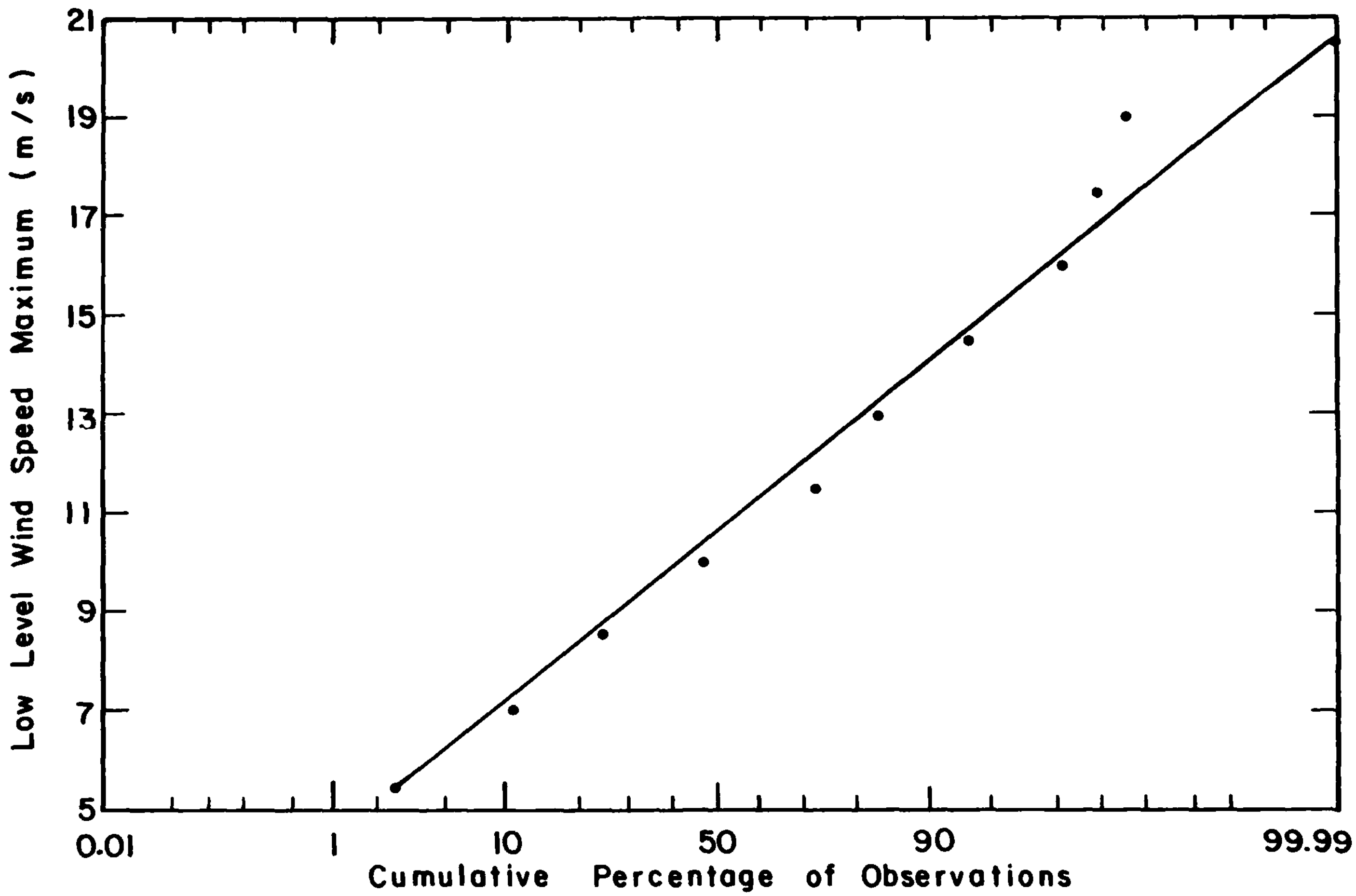

Figure 4. Probability plot of low level wind speed maximum data. (0000 and 1200 GMT combined)

Both were then plotted on normal probability paper (Figs. 6 and 7). Once again, occurrences at both 1200 and 0000 GMT appeared to follow the normal distribution.

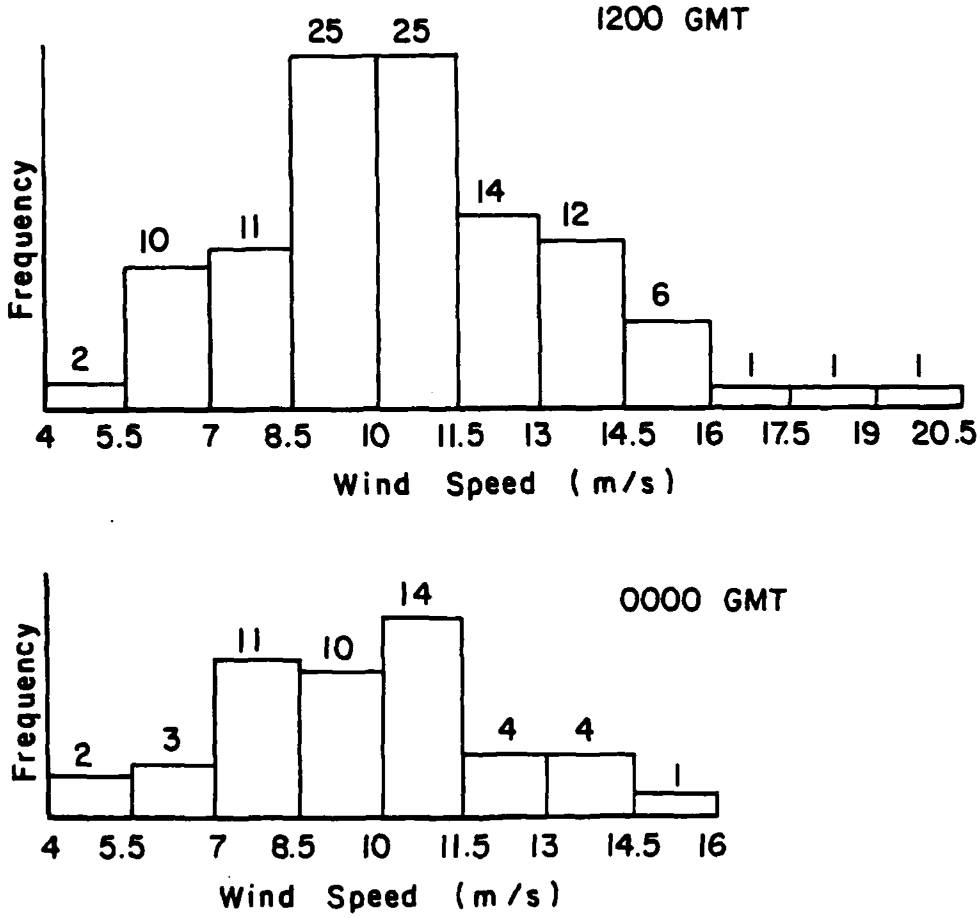

Figure 5. Frequency plot of 1200 GMT and 0000 GMT occurrences of low level wind speed maximum

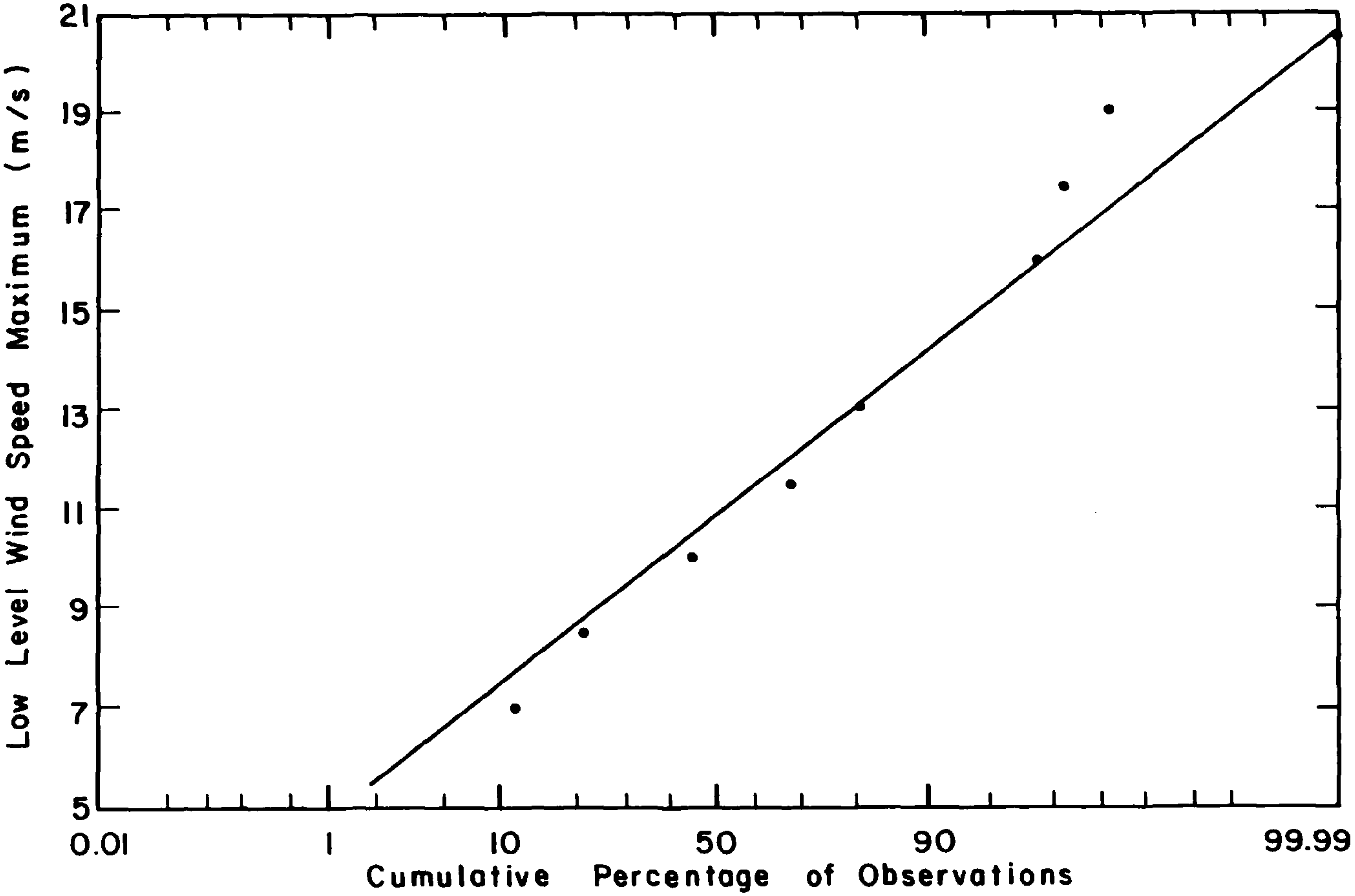

Figure 6. Probability plot of 1200 GMT low level wind speed maximum data

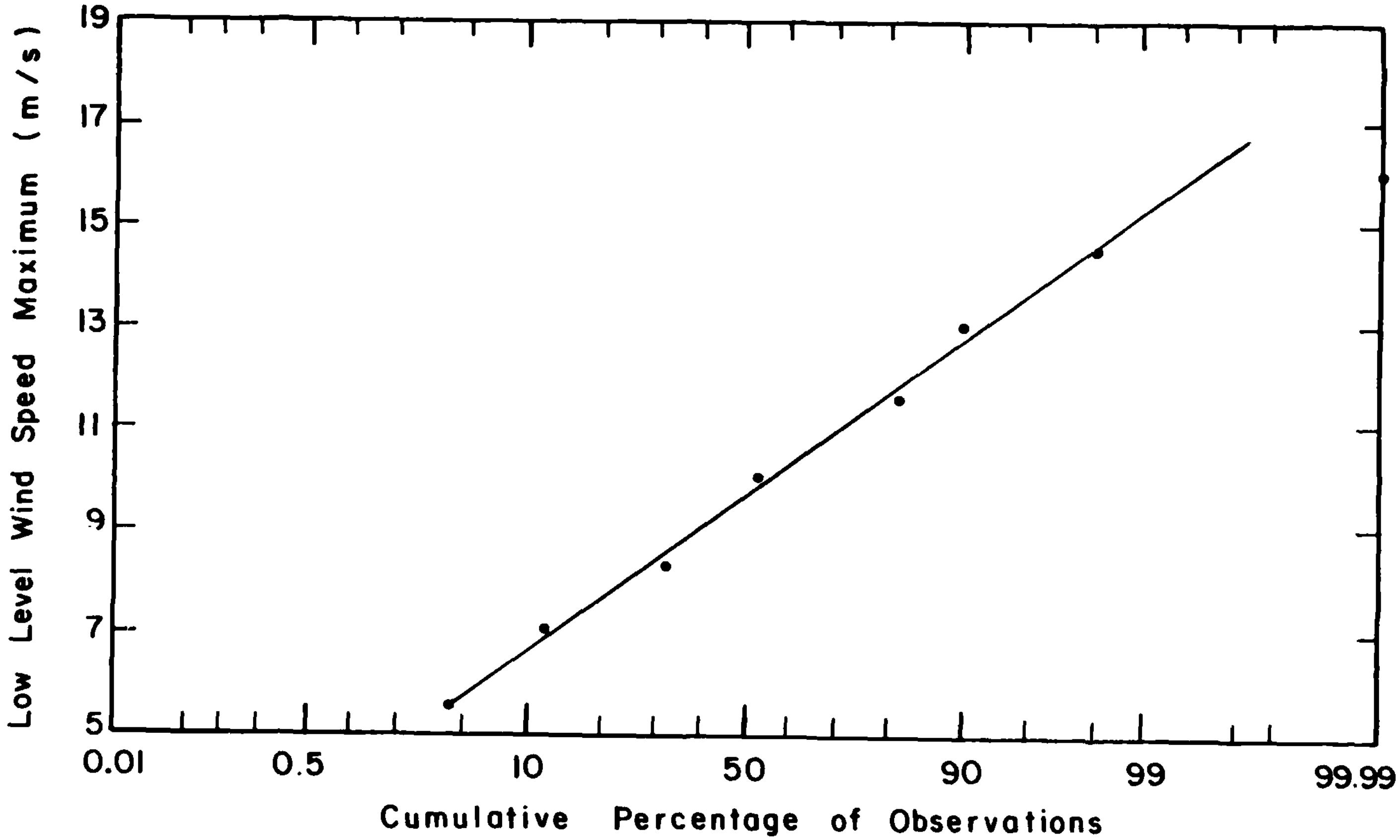

Figure 7. Probability plot of 0000 GMT low level wind speed maximum data

IV. THE LOW LEVEL WIND SPEED MAXIMUM AND THE COASTAL WIND MAXIMUM

Yu and Wagner (1970) and Choi (1984) presented evidence for the existence of a nighttime wind speed maximum along the Texas coastline. Choi (1984) examined the complete record of the tower wind data from Port Aransas. He found that during the summer months (May - August) the maximum frequency of occurrence of the coastal wind maximum is at 0000 CST (0600 GMT) with a secondary maximum at 2000 CST (0200 GMT). A primary minimum occurred at 0800 CST with a secondary minimum at 1100 CST. During the summer months, 73 percent of the occurrences of the coastal wind maximum were recorded during the nighttime hours (2000 CST - 0700 CST). During August, 62.4 percent of the occurrences were during the nighttime hours with a primary maximum at 0000 CST (9.1 percent) and a secondary maximum at 2000 CST (8.5 percent).

As expected, since it was a portion of the information analyzed by Choi, the month of August, 1977 followed these same statistics very closely. As with Choi's data, the maximum wind was determined by selecting the highest wind speed during the calendar day. If the same maximum wind occurred more than once during the day, each occurrence was counted individually.

A total of 64 occurrences were analyzed. Of these, 42 or 65.6 percent occurred during the nighttime hours. Both 2300 and 0000 CST tied for the primary maximum with 12.5 percent. A secondary maximum at 1900 CST of 10.9 percent also occurred. As well as

supporting Choi's conclusion that a nocturnal surface wind maximum occurs along the coastline, these statistics also support the conclusion that August, 1977 was not significantly different from the average August statistics from the period Choi analyzed.

Choi also concluded that a downward transfer of momentum from the low level jet was the mechanism for the nocturnal coastal surface wind maximum. Carrying this conclusion a step further, this study attempts to establish whether or not a relationship exists between the speed of the low level wind speed maximum and the surface wind speeds along the coastline. The first step was to regress the first reported level of winds above the surface against the Port Aransas nocturnal wind speed maximum. This was done using 1200 GMT data for all five radiosonde stations for each day during which a nocturnal wind maximum occurred. There were only five days during the month which did not have a nocturnal wind maximum. However, some stations were missing upper level wind data. Therefore, about 21 occurrences were analyzed for each station. The resulting correlation coefficients are shown below.

STATION	LEVEL	CORRELATION COEFFICIENT	NO. OF OCCURRENCES
Victoria	1000 mb	.448	20
Brownsville	1000 mb	.288	19
Longview	1000 ft	.027	20
Del Rio	2000 ft	-.023	23
Stephenville	2000 ft	-.144	22

The correlation coefficients show no significance. In fact, Del Rio and Stephenville even showed negative

correlations.

The next step was to regress the 1200 GMT low level wind speed maximums for each of the five stations against the nocturnal wind maximum at Port Aransas. The results of these regressions are shown below.

STATION	CORRELATION COEFFICIENT	NO. OF OCCURRENCES
Victoria	.486	17
Brownsville	.754	15
Longview	.009	14
Del Rio	-.109	23
Stephenville	-.111	21

Once again, the correlation coefficients for Longview, Del Rio, and Stephenville were unimpressive. Del Rio and Stephenville again had negative coefficients. The coefficient for Victoria was fair at best. Brownsville, however, did show a relatively good correlation coefficient.

In each of the preceding correlation studies, we are dealing with spacial separation of the stations and a temporal difference in the data. The radiosonde data is fixed at 1200 GMT whereas the Port Aransas wind maximum was capable of occurring at any hour. Perhaps we should not be too surprised at the very weak correlations which we found.

Even though this attempt to relate the low level wind speed maximum to the nocturnal wind speed maximum was not very successful, we felt it might still be possible to discover a relationship between the surface winds at Port Aransas and the low level wind speed maximum. We took the 1200 GMT occurrences of the low level wind maximum at all five stations and related them

to the corresponding 0600 CST Port Aransas surface wind speeds. Once again, regressions were accomplished. The results are listed below.

STATION	CORRELATION COEFFICIENT	NO. OF OCCURRENCES
Victoria	.902	19
Brownsville	.884	19
Longview	.031	16
Del Rio	.306	26
Stephenville	.271	24

Victoria and Brownsville showed a very strong correlation. The other three displayed weak correlations. We felt that this proved a possible direct relationship between the low level wind speed maximum and the Port Aransas surface wind speed. To further explore this conclusion, a regression between the 0000 GMT low level wind speed maximums at Victoria and Brownsville against the 1800 CST Port Aransas surface wind speeds was done. The results are presented below.

STATION	CORRELATION COEFFICIENT	NO. OF OCCURRENCES
Victoria	.771	10
Brownsville	.652	14

Although the correlation coefficients were not as high as for the 1200 GMT regression, they were still high enough to support the original conclusion.

These latter two correlation studies suggest that if radiosonde data was available at the observed time of the Port Aransas wind maximum (about 0600 GMT) that a strong correlation would be found between them (instead of the weak correlation as found in the first

two studies of this section). It is unfortunate that radiosonde observations at 0600 GMT for Brownsville and Victoria are not available to verify this.

V. RELATIONSHIP BETWEEN THE LOW LEVEL WIND SPEED MAXIMUM AND THE VERTICAL WIND SHEAR

The vertical wind shear is the local variation with height in the horizontal velocity vector. It can be caused by either a change in wind direction with height or a change in wind speed with height (or both). This study concerns itself with vertical wind shears caused by a rapid change in wind speed over a short distance. In this case, the distance was defined to be 200 meters and the low level wind speed maximum was responsible for the change in wind velocity in the vertical.

Tables 3 and 4 give the 0000 GMT and 1200 GMT maximum and average wind shears respectively for all five radiosonde stations. The maximum wind shear was determined by examining the soundings associated with each occurrence of the low level wind speed maximum. The maximum change in wind speeds which occurred over a distance of at least 200 meters was chosen. This change in wind speeds was then taken as the maximum wind shear which had occurred within a 200 meter distance. The average wind shear was similarly obtained. The change in wind speeds between the low level wind speed maximum and the surface wind was determined and was then divided by the altitude of the low level wind speed maximum above the surface. This gave the change in wind speed per meter. By multiplying by 200 meters, the average wind shear occurring over a distance of 200 meters was obtained.

Table 3. Maximum wind shears (m/sec) in 200 meters.

Date	VCT		DRT		BRO		SEP		GGG	
	0000	1200	0000	1200	0000	1200	0000	1200	0000	1200
1	--	5.8		3.1		6.2		3.5	--	--
2	1.5	3.1		3.1		4.8		5.0	--	0.7
3		2.7	0.7	2.8	1.7	4.8		7.4	--	--
4		1.9		2.8		5.2		10.4		6.3
5	1.9	--		3.5	1.7	4.1		8.4	--	6.8
6	1.9	--	2.1	--	1.4	--		--	--	--
7	1.0	3.1		1.7			4.0	8.4	3.4	3.4
8		--		3.1				5.9	--	3.4
9	2.7	--	2.1	3.5	2.1			6.9	1.4	
10			0.9	3.5	1.4	4.1	2.5	6.4	--	2.3
11	1.5		1.0	2.8		2.8	1.0	7.4		--
12				1.4	3.1	4.5			--	
13		1.0		3.8	--		1.4	5.5		--
14	--	--	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--
16		3.5	--	2.8	--	5.2	--		--	3.8
17		2.7	1.7	1.9	2.4	1.4		9.4	--	8.5
18	1.5			2.8		2.4		3.0	--	
19		4.6		3.5	--	--		6.4	--	1.9
20		5.4	0.7	1.7	2.1	1.1		2.4	1.0	4.6
21		5.8	0.7	3.5	1.7	6.2		4.0	--	3.2
22	3.5	5.0	1.4	2.4	--	1.0		3.0	--	
23		4.3		2.2		5.9		7.9		4.7
24		5.4		2.8	1.4	5.5		3.0		2.1
25	1.5	3.5		3.1	1.4	5.2		6.0	0.7	--
26		6.5	2.1	2.9	2.4	5.5		8.4		8.5
27	1.7	5.0	3.1	3.8	--		2.5	4.6	0.7	
28		2.7	1.0	1.0	2.1	5.5		5.0	4.5	4.2
29				2.8		--			--	1.1
30	2.2	1.5			1.4		5.0			4.0
31		2.3		3.1	1.4		4.0			

-- indicates that data was missing

Table 4. Average wind shears (m/sec) in 200 meters.

	VCT		DRT		BRO.		SEP		GGG	
Date	0000	1200	0000	1200	0000	1200	0000	1200	0000	1200
1	--	2.9		1.6		3.8		1.9	--	--
2	1.5	1.6		2.2		2.6		5.0	--	0.4
3		2.7	0.9	2.1		4.8		7.4	--	--
4		1.1		2.1		2.7		4.6		6.3
5	1.9	--		2.4	1.0	1.5		8.4	--	6.8
6	0.8	--	0.5	--	1.0	--		--	--	--
7	0.8	1.4		1.4			1.8	4.0	3.4	3.4
8		--		1.9				4.0	--	2.3
9	2.7	--	1.2	1.7	2.1			4.0	0.4	
10			0.8	1.6	1.4	1.3	1.6	3.2	--	2.3
11	1.5		0.5	1.4		1.1	0.2	3.2		--
12				1.2	3.1	2.4			--	
13		0.6		3.8	--		0.3	2.6		--
14	--	--	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--
16		1.6	--	1.3	--	5.2	--		--	3.8
17		1.6	0.7	1.9	2.4	1.0		9.4	--	8.5
18	1.5			1.7		1.7		3.0	--	
19		2.3		1.9	--	--		6.4	--	1.9
20		3.1	0.4	1.5	2.1	1.1		1.5	0.4	4.6
21		3.4	0.5	1.6	1.7	3.9		2.8	--	3.2
22	3.5	2.7	0.3	1.3	--	1.0		1.8	--	
23		2.4		2.2		2.6		4.0		4.7
24		3.4		2.8	0.9	3.1		3.0		2.1
25	1.5	2.7		1.6	1.4	2.2		6.0	0.5	--
26		2.1	2.1	2.5	2.4	2.3		4.8		8.5
27	1.3	1.5	1.3	2.4	--			0.8	3.3	0.6
28		1.5	0.6	0.7	2.1	3.2		2.3	1.2	4.2
29				0.9		--			--	0.7
30	1.5	1.5			1.4				3.6	2.6
31		1.3			1.7	0.9			2.0	

-- indicates that data was missing

Figure 8 gives a frequency distribution plot for the maximum wind shear. This distribution was found to follow the log-normal distribution (Fig. 9). Figure 10 gives the frequency distribution plot for the average wind shear. It also followed a log-normal distribution (Fig. 11).

Our first interest was to determine how strong the correlation was between the low level wind speed maximum and the maximum wind shears just presented. A regression of a combination of both the 0000 GMT and 1200 GMT maximum wind shears versus the low level wind speed maximum was done (Fig. 12). The correlation coefficient (.430) indicates a weak correlation. Next, the 0000 GMT and then the 1200 GMT maximum wind shears were regressed against the low level wind speed maximum (Fig. 13). The correlation coefficient for 0000 GMT was .561 while the 1200 GMT coefficient was .406. Neither coefficient was exceptionally strong, but the 0000 GMT coefficient was notably higher than that at 1200 GMT. A similar regression was performed for individual data from each of the five radiosonde stations and in each case the 0000 GMT coefficient was higher.

We then considered the relationship between the average wind shear and the low level wind speed maximum. The regression for the 0000 GMT and 1200 GMT average wind shears combined versus the low level wind speed maximum gave a correlation coefficient of .187. When just the 0000 GMT shears were regressed, a coefficient of .209 was determined and when just the 1200 GMT shears were regressed, the coefficient was .137. Both coefficients were considered insignificant, although the general trend of a higher 1200 GMT than 0000 GMT

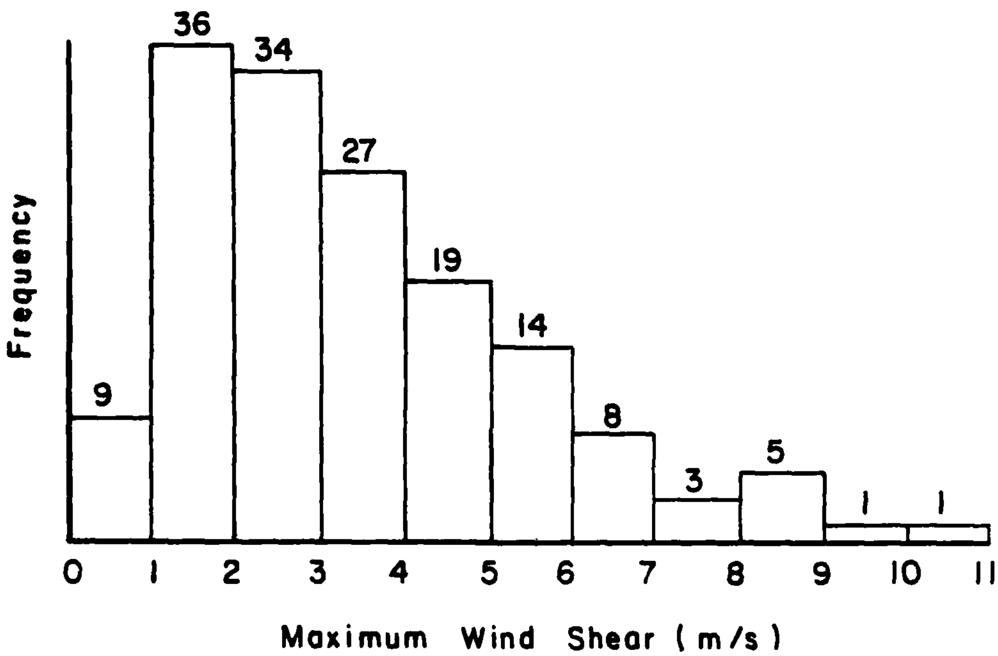

Figure 8. Frequency plot of maximum wind shears in 200 meters

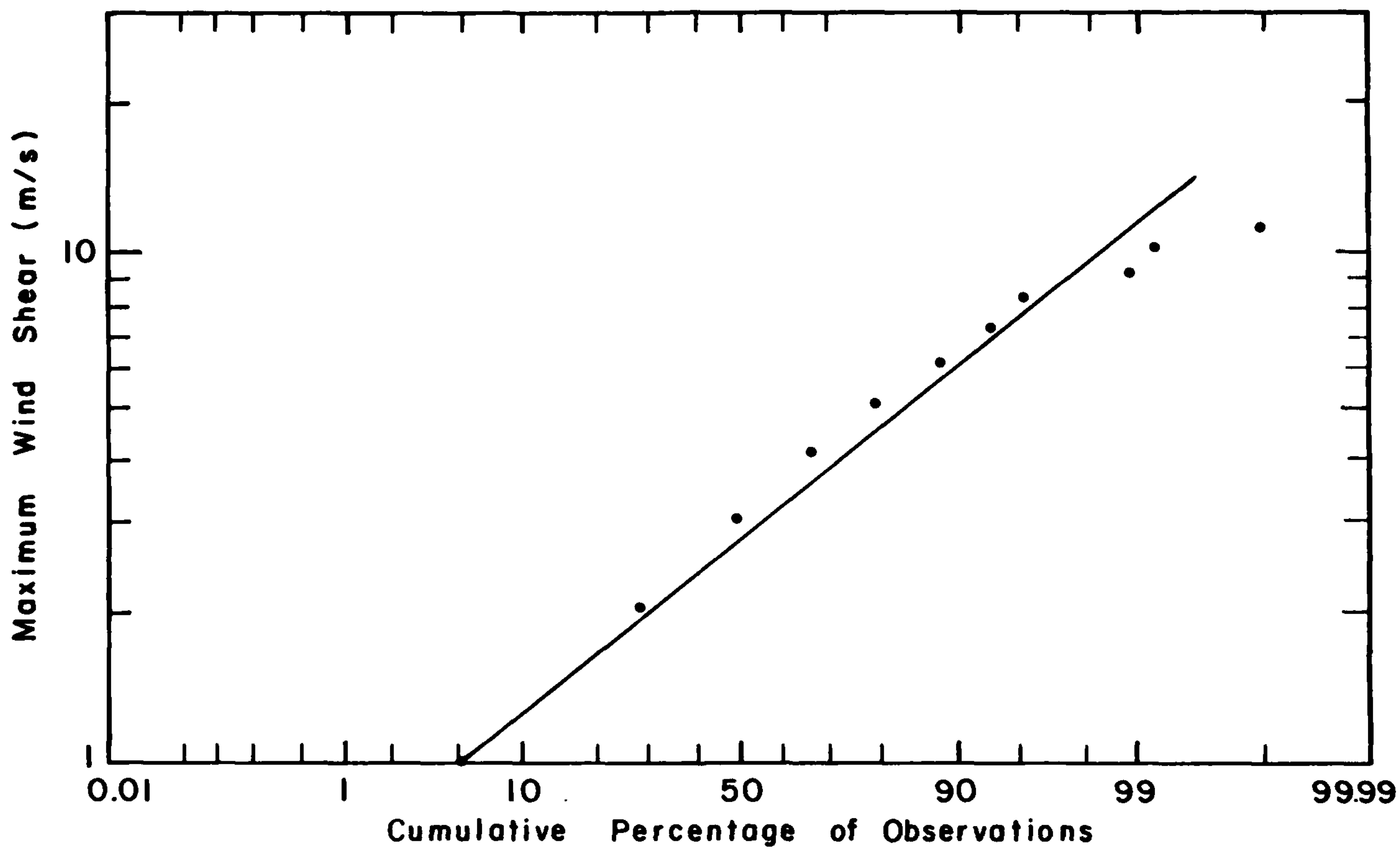

Figure 9. Probability plot of maximum wind shear in 200 meters

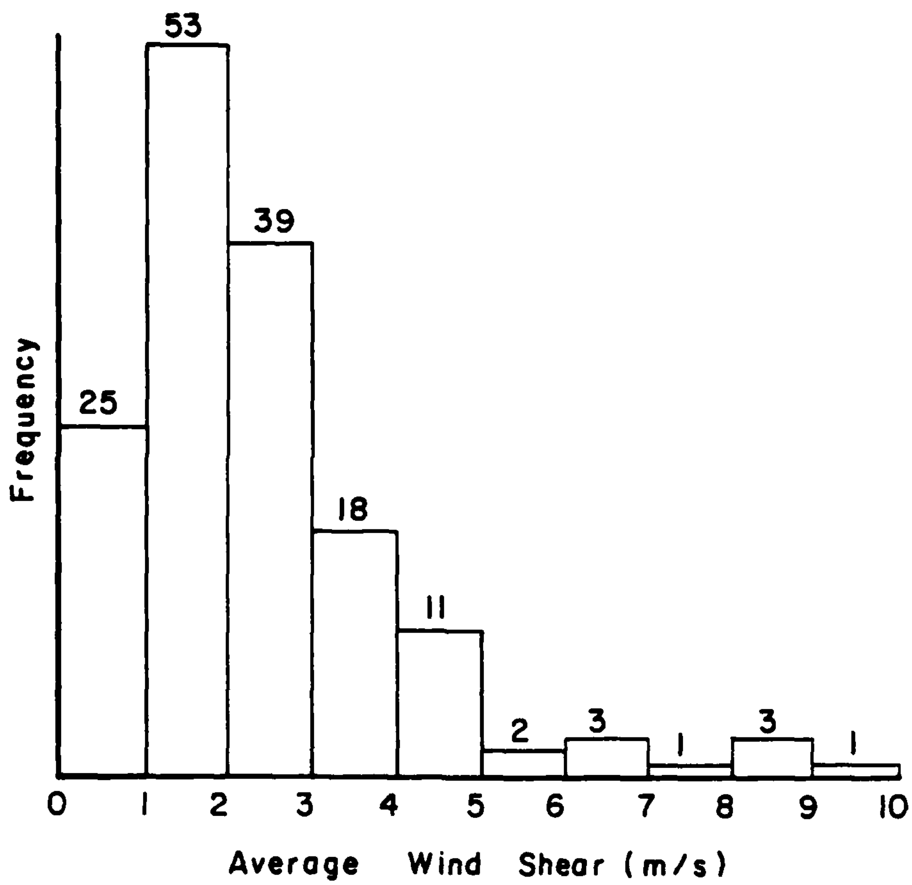

Figure 10. Frequency plot of average wind shear in 200 meters

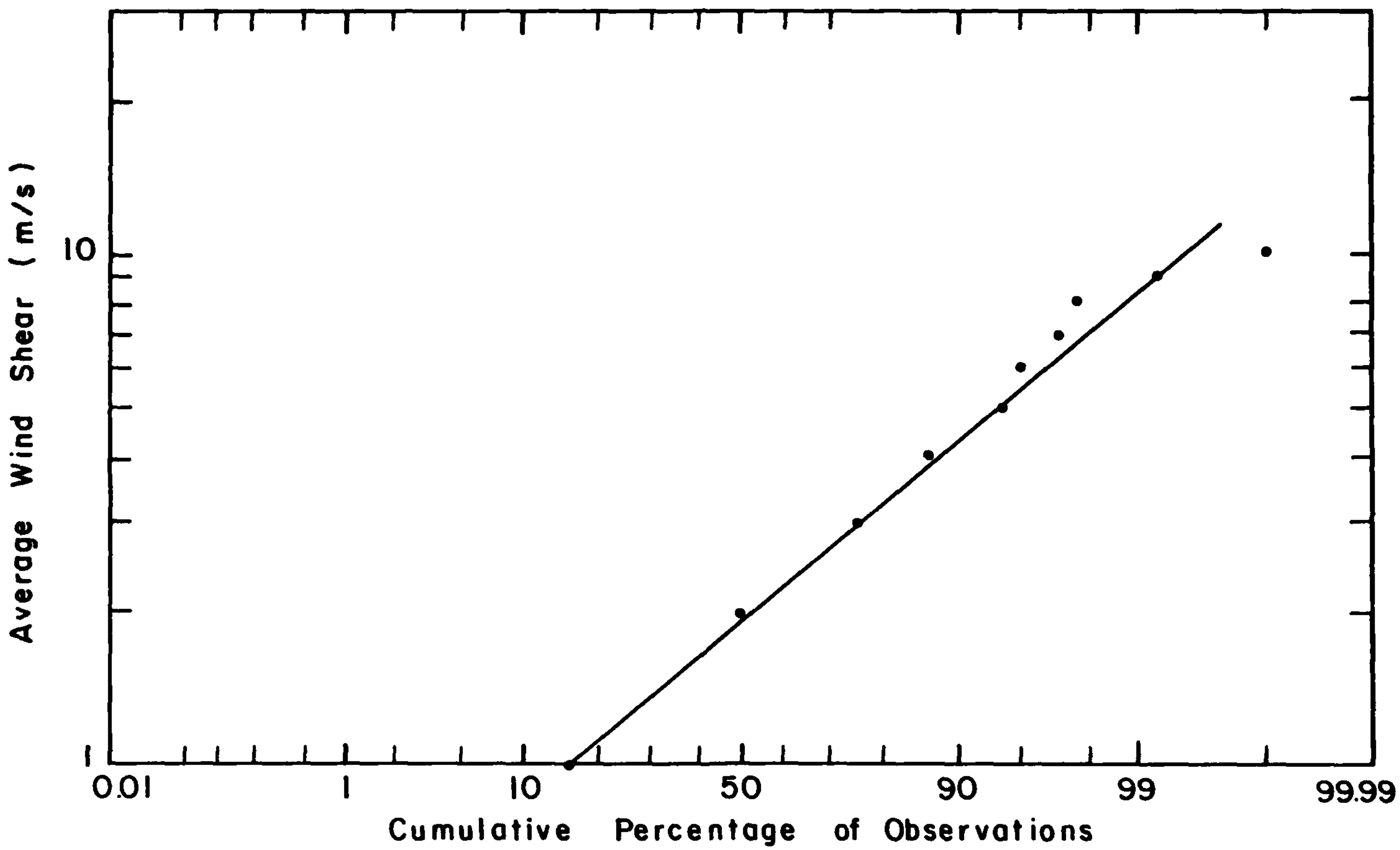

Figure 11. Probability plot of average wind shear in 200 meters

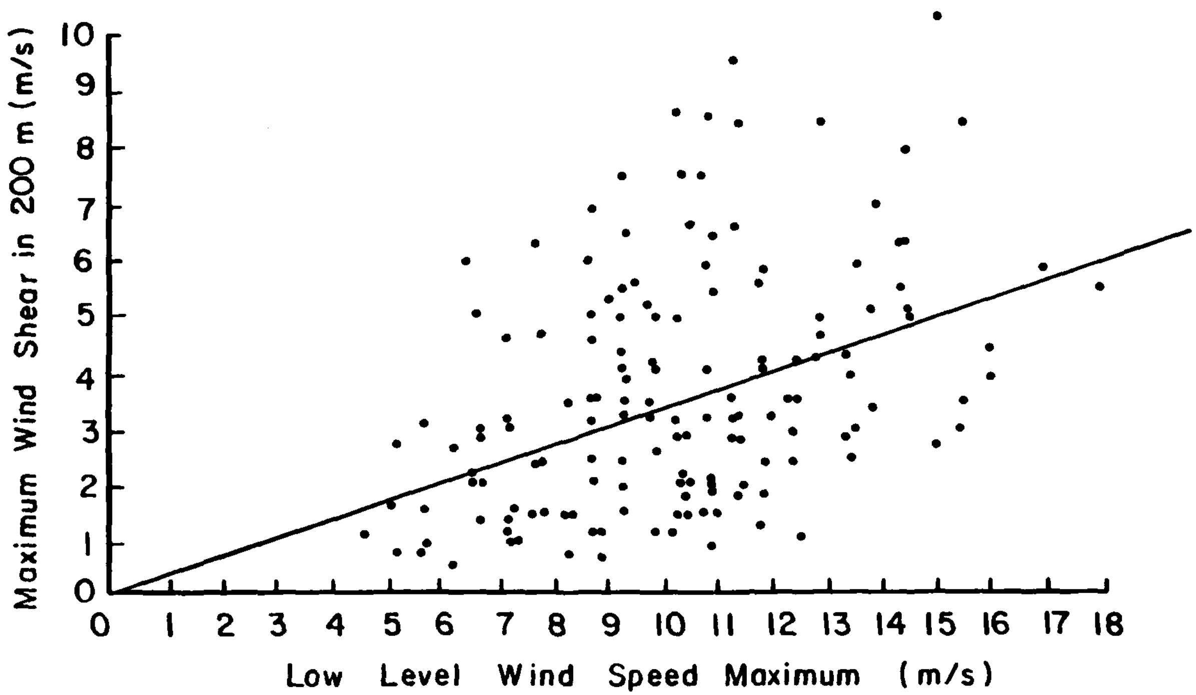

Figure 12. Maximum wind shear in 200 meters versus low level wind speed maxima regression plot

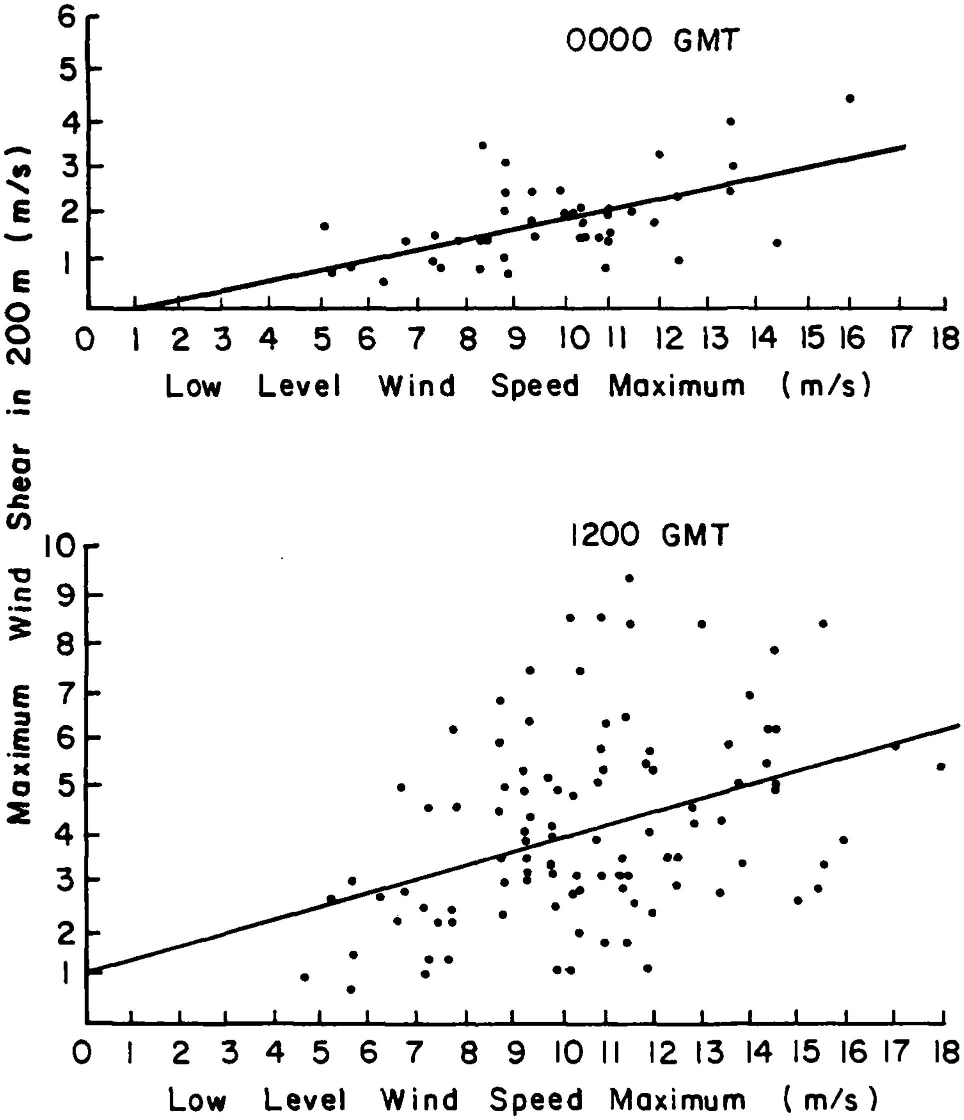

Figure 13. Regression plots of maximum wind shear in 200 meters versus 0000 GMT and 1200 GMT low level wind speed maxima

coefficient was again noted.

We also looked at the altitude of the low level wind speed maximum (Table 5) to see if it correlated with the maximum and average wind shears. To do this, the 1200 GMT maximum and average wind shears were regressed against the altitude of the low level wind speed maximum. The results are given below.

STATION	CORRELATION COEFFICIENTS		NO. OF OCCURRENCES
	Max. Shear	Avg. Shear	
Victoria	.039	-.423	20
Brownsville	-.637	-.761	19
Longview	-.654	-.724	17
Del Rio	-.025	-.586	27
Stephenville	-.509	-.668	25

All the coefficients for the average shear, with the exception of Victoria, were fairly good. For the maximum shear, Victoria and Del Rio had poor coefficients while the other three were fairly good. In all instances, the coefficients for the average shear were higher than the maximum shear. Notice too that these correlation coefficients are negative (except for the maximum shear at Victoria). An earlier study by the author established that the low level wind maximum is not significantly correlated with altitude (a correlation coefficient of .082). Thus, the negative correlations for wind shear versus altitude are to be expected. Higher shears occur when the wind maximum is at lower altitudes.

Table 5. Altitude (m) above MSL of the low level wind speed maximum.

Date	VCT 0000	VCT 1200	DRT 0000	DRT 1200	BRO 0000	BRO 1200	SEP 0000	SEP 1200	GGG 0000	GGG 1200
1	--	610		1219		610		1219	--	--
2	305			914		762		610	--	2286
3		305	914	914	2743	458		610	--	--
4		1067		1219		762		914		305
5	305	--		1067	610	1377		762	--	305
6	914	--	2134	--	762	--		--	--	--
7	914	1067		1219			1390	914	305	762
8		--		1067				914	--	1219
9	305	--	1067	1219	305			914	2438	
10			1219	1219	458	1219	914	914	--	610
11	305		1982	1219		914	1543	914		--
12				1067	305	610			--	
13		914		610	--		1219	914		--
14	--	--	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--
16	--	914	--	1551	--	610	--		--	610
17		610	2134	1067	305	914		610	--	305
18	458			914		762		610	--	
19		610		914	--	--		610	--	610
20		762	2134	1219	305	1542		1377	1829	305
21		610	1681	1219	305	610		914	--	762
22	305	610	1823	1219	--	1527		1067	--	
23		914		914		914		914		610
24		610		610	610	610		610		610
25	305	762		1219	458	1067		610	2286	--
26		914	914	1219	305	914		914		305
27	610	1520	1219	1219	--			1515	1219	2134
28		1371	1829	914	305	610		1219	2134	610
29				2134		--			--	1219
30	914	305			305			914		914
31		610		914	610			914		

-- indicates that data was missing

The same analysis was done for the 0000 GMT maximum and average wind shears. The results of this analysis are presented below.

STATION	CORRELATION COEFFICIENTS		NO. OF OCCURRENCES
	Max. Shear	Avg. Shear	
Victoria	-.278	-.620	11
Brownsville	-.228	-.792	15
Longview	-.442	-.937	6
Del Rio	-.220	-.712	12
Stephenville	-.097	-.439	5

The results were much the same as for 1200 GMT. The coefficients for the average shear were much higher than for the maximum shear and the correlation coefficients were negative. The 0000 GMT data did suffer from a more limited number of occurrences than for 1200 GMT.

VI. VAPOR MASS FLUX CALCULATION

Over 90 percent of the water vapor in the atmosphere is contained within the lowest 5 kilometers with 70 percent contained in the lowest 3.5 kilometers (UNESCO, 1978). As mentioned previously, the low level wind speed maximum normally occurs within the lowest 1 to 1.5 kilometers of the atmosphere. Obviously, the high concentration of water vapor in the lower atmosphere makes the low level wind speed maximum an extremely important mechanism for the transport of water vapor in southern and eastern Texas. Frequently, the effect of the low level wind speed maximum is neglected when mass flux determinations are made. This is because it is not normally reflected at any of the standard atmospheric levels. To test the significance of errors introduced into mass flux calculations when the low level wind speed maximum is neglected, a simple calculation was performed.

The total vapor mass flux ($\dot{M}_v$) between the surface and 850 millibars was calculated using two different methods. These levels were chosen because we were interested in processes affecting the lower portion of the atmosphere and because the effects of the low level wind speed maximum are not generally deemed important above 850 mb. The following equation was used for the calculations:

$$\dot{M}_v = q_v \rho V A$$

$\dot{M}_v$ - vapor mass flux (kg/sec)

q_v - specific humidity

ρ - air density (kg/m^3)

V - velocity (m/sec)

A - area (m^2) (assumed unit width)
The calculations were performed for 100 of the 157 occurrences of the low level wind speed maximum previously mentioned. These 100 occurrences were chosen randomly, although many of the 157 had to be eliminated due to the lack of necessary data. The first of the two methods involved only information from the surface and the 850 millibar level. The second method involved additional data between these levels which is routinely available to most meteorologists via the teletype machine.

The first task was to gather data. Teletype information from all five radiosonde stations was collected and decoded. This pool of information yielded both wind and moisture data. Wind speeds for the surface and 850 millibar level were available as well as wind speeds for every 305 m (1000 ft) in between. The moisture variables used were the temperature (T) and dew point temperature (T_d). The temperature and dew point temperature were reported at the surface and 850 mb level as well as at significant levels between the surface and 850 mb. Significant levels were as defined in the Federal Meteorological Handbook No. 4.

For each of the 100 occurrences, there would be between six and ten data levels. Each level would have either wind data, temperature data, moisture data, or a combination of the three. Fortunately, the levels were close enough together that linear interpolation could be used to obtain temperature and moisture variables for levels that just had wind data, and vice versa. After each level had temperature, moisture, and wind speed values established (either by observational data or by

linear interpolation), the specific humidity was computed.

The first step in computing the specific humidity was to determine the relative humidity (RH) in decimal form. First, the temperature and dewpoint temperature for each level were plotted on a Stüve thermodynamic diagram. Next, a mixing ratio (w) and saturation mixing ratio (w_s) were read off the diagram for each level. The relative humidity (in decimal form) was then computed using the relationship:

$$RH = w/w_s$$

The next step was to compute the vapor pressure (e). Since the temperature at each level was different, a saturation vapor pressure (e_s) was computed for each level.

$$e_s = 1.013x10^5 \exp(13.319t_r - 1.976t_r^2 - .645t_r^3 - /13t_r^4)$$

(Raudkivi, 1952)

t_r : 1 - (373.15/T); T in ^oK

e_s : kPa

With the relative humidity and saturation vapor pressure at each level, it was a simple matter to compute the vapor pressure.

$$e = (RH)(e_s)$$

Finally, the specific humidity was determined by plugging in the pressure and vapor pressure for each level.

$$q_v = .622(e/P)$$

The computation of the density required a straight forward application of the ideal gas law.

$$\rho = P/RT$$

This left the area as the last factor necessary to compute the mass flux.

As mentioned previously, a unit width was assumed for the area. The problem was determining a height interval to go along with the unit width. For each occurrence, several discrete points were available which had different velocities, densities, and specific humidities. The vertical distance between each of these discrete points was determined. The desired height interval for each point was then calculated by adding one half of the distance to the closest point above to one half of the distance to the closest point below. The only exceptions were the surface and the 850 mb levels. Since they represented the bottom and top of the area of interest, their lengths were considered to be simply one half the distance to the one point above or below them respectively.

All the necessary variables were then available to compute the total vapor mass flow.

$$\dot{M}_V = q_V \rho V A$$

The mass flux was first determined using only the two standard levels (surface/850 mb). Then it was recomputed using all the available levels from the surface up to 850mb. The following values for the mean and standard deviation for the 100 occurrences using both methods were determined.

	$\dot{M}_V$(kg/sec) (surface/850 mb only)	$\dot{M}_V$(kg/sec) (all levels)
$\bar{X}$	103.82	166.52
S	40.17	61.53

The percentage difference was very significant:

% difference = ((166.52 - 103.82)/103.82) = .604 or 60.4%

Obviously, ignoring information from the levels in between the surface and 850 millibars can give a gross underestimation of the average total vapor mass flux.

VII. CONCLUSIONS

Future studies should examine the low level wind speed maximum's potential significance in solving practical problems. This study showed the significance of the low level jet in several applications.

One of these applications is the computation of water vapor transport. A simple vapor mass flux computation showed the inaccuracy of neglecting the low level wind speed maximum. Any future computations of a similar nature should not be based strictly on information from the standard atmospheric levels. All available wind and moisture information should be utilized. Particularly since so much water vapor is contained in the lower atmosphere and since the low level wind speed maximum can represent a large change in wind speeds within a short distance in the atmosphere.

A similar application is in the field of air pollution engineering. Sisterson and Frensen (1978) showed the inability of power-law wind profile relations to predict the low level wind speed maximum. They concluded that the power-law profile consistently underestimated the low level wind speed. Hence, any computations of the dispersion or transport of pollutants must take into account the difference between the actual and theoretical wind profiles.

A third potential application is to relate the low level wind speed maximum to wind speeds along the Texas coastline. Attempts to relate the 1200 GMT low level wind speed maximum data to the Port Aransas nocturnal wind speed maximum showed very weak correlations. However, when the 1200 GMT and 0000 GMT

Victoria and Brownsville low level wind speed maximums were related to the 0600 CST and 1800 CST Port Aransas surface winds, the correlations were very high. This would tend to show a possible direct relationship between the upper level winds at Victoria and Brownsville and the Port Aransas surface winds. This would suggest that coastal surface winds might be used to forecast the speed of the low level jet at Victoria and Brownsville (or vice-versa). Unfortunately, radiosonde data at these stations is only available at 0000 GMT and 1200 GMT so this hypothesis can't be completely tested.

A fourth possible application is in the study of wind shears. This study attempted to determine if a relationship existed between the average or maximum wind shear at a station and the speed and altitude of the low level wind speed maximum at the same station. The initial results were not promising but deserve further study, especially in light of the importance of low level wind shear to aircraft operations.

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VITA

PII Redacted

Wendell Troyce Stapler [redacted] the son of Betty Jean Stapler and W. T. Stapler. After completing his work at Conroe High School, Conroe, Texas, in 1974, he joined the United States Air Force. He received the degree of Bachelor of Science from the University of Texas in May, 1981. In the following years he continued to serve in the United States Air Force as a meteorologist. Sponsored by a program conducted by the Air Force Institute of Technology, he entered the Graduate School of The University of Texas in September, 1984.

[redacted]

This thesis was typed by Barbara A. Murphy.